TME

RECORDING STORAGE TUBES

B. COURTAN

J. DESCHAMPS

THOMSON-CSF

THOMSON - CSF - GROUPEMENT TUBES ELECTRONIQUES 8, rue Chasseloup - Laubat - 75 - Paris 15e - Tél.: 566.70.04
THOMSON - CSF ELECTRON TUBES, INC. 50 Rockefeller Plaza - New-York, N.Y. 10020, U.S.A. Telephone (212) 489 0400

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SUMMARY

The TME's are recording storage tubes with electrical output and non-destructive read-out. After a description and an analysis of the reading mode (coplanar control reading), different processes of storage target charging (writing and erasing) are described. The charges can be deposited either on the side of the storage target facing the reading gun or on the opposite side in the case of a very thin target. Practically speaking, these two writing modes correspond to 2 types of tubes :

- Single-ended tube type where erasing, writing and reading sequences are accomplished with a single gun ;
- Double-ended tube type where writing and reading are simultaneously performed by corresponding guns located on both sides of a thin target ; erasing can be performed by either one or the other gun.

Detailed considerations related to single gun tubes are then given for types currently available (TME 1238 and TME 1239) and for developmental tubes (electrostatic deflection tube, high writing speed tube, high resolution tube . . . . .).

The operating principle and technology of developmental dual-gun tubes are also described with technical data concerning a tube of this family the TME 1496.

I - GENERAL

Storage tubes are C. R. T. ' s which receive and store information in the form of charge patterns and deliver this information in the form of a light image or an electrical signal.

The TME's or Recording Storage Tubes represent a particular category of this family presenting the two following characteristics :

1/ the stored information is delivered in the form of an electrical signal ;
2/ the read-out is non-destructive i. e. retention time is theoretically infinite.

In order to have a clearer concept of this, it is of interest to explain the difference between TME's and other storage tubes :

- The D. V. S. T. has a non-destructive read-out like the TME's but delivers a light output.
- The EBIC scan converter delivers an electrical output like the TME's but has a destructive read-out.

The storage target of TME's can be made either of a storage mesh modulating the reading beam or of a planar target allowing coplanar control reading.

In this paper, only the second technique is considered since it is the technique which makes possible the development of high performance tubes, and therefore constitutes the major part of our studies.

We must express here our acknowledgements to the"Service Technique des Telecommunications de l'Armée de l'Air"which has partly supported this work from its beginning.

II - BASIC OPERATING PRINCIPLES OF TME's

The basic characteristic of the TME's (single or double-ended types) consists of using a coplanar control target in order to obtain a non-destructive read-out of the recorded signal.

Before examining the detailed mechanism of the non-destructive read-out, it is necessary to remember briefly the charge and discharge process of an insulating surface through secondary emission.

II - 1 Equilibrium potential of an insulator by secondary emission

II - 1 - 1 Secondary emission ratio

When a material is bombarded by primary electrons, secondary electrons are emitted from its surface. The ratio between the number of secondary electrons and the number of primary or incident electrons is called the secondary emission ratio δ. Depending on the material, δ can differ but for a given material it is a function of primary electrons energy eV_{pr}. Figure 1 shows the variation of δ as a function of Vpr, the shape of the curve being the same for any material. δ is small for low energies, increases rapidly to a maximum, then decreases more slowly with further increase of primary energy. The two points where $\delta = 1$ correspond to the cross-over potentials Vpr_1 and Vpr_2 and are of particular interest.

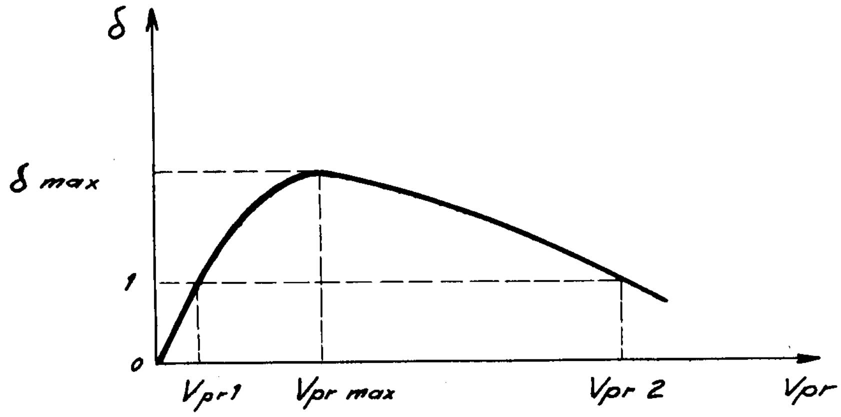

Fig 1 : Variation of secondary emission ratio δ versus energy of incident electrons

In fact, two cases are to be considered :

- $\delta < 1$ for $Vpr < Vpr_1$ or $Vpr > Vpr_2$

δ being lower than unity, the amount of secondary electrons is lower than the amount of primary electrons. In the case of an insulator, its surface is negatively charged.

- $\delta > 1$ for $Vpr_1 < Vpr < Vpr_2$

δ being higher than unity, the amount of secondary electrons is higher than the amount of primary electrons. In the case of an insulator, its surface is positively charged. Practically Vpr1 is of the order of 50 V and Vpr2 of the order of several kV. As for δ maximum, it can vary within a large range depending on the material.

II - 1 - 2 Equilibrium potential

In TME's, primary electrons are accelerated so that Vpr varies from 0 to Vpr max. (the acceleration of primary electrons is the potential difference between the bombarded material and the emissive cathode).

2 operatings modes can be considered :

- the so-called "low velocity electron" mode where $Vpr < Vpr1$ and $\delta < 1$
- the so-called "high velocity electron" mode where $Vpr > Vpr1$ and $\delta > 1$

In the case of a dielectric, the result will be that the surface of the dielectric will be charged in a negative or a positive direction according to the mode used.

In the case of a dielectric bombarded by low velocity electrons ($\delta < 1$), the potential of the surface decreases down to 0 V. For this value, an equilibrium is established since the dielectric potential being at the cathode potential, the primary electrons cannot reach the dielectric. The equilibrium potential of a dielectric material bombarded by low velocity electrons is then zero (this is true at first approximation when the thermal energy of electrons is not taken into account).

It is to be noted that, when the equilibrium potential is reached, the dielectric is no longer bombarded by electrons and it is obvious that this will be the same if the dielectric surface is shifted to a negative potential with respect to the cathode. This characteristic is properly used in non-destructive read-out tubes.

It is also to be noted that in the case when high velocity electron bombardment is used, the equilibrium potential reached is that of the collector electrode ; in this case the dielectric is constantly bombarded by the primary electrons whatever the potential of the target may be with respect to the equilibrium potential.

II - 2 Non destructive read-out by coplanar control

This reading mode is roughly characterized by :

- the use of an electron beam called the reading beam, having a constant density and approaching the target orthogonally over its surface.
- the use of a planar target with a fine periodic structure including dielectric and conductive areas alternatively.
- the presence on the dielectric areas of a charge pattern deposited by the writing beam.

The recorded charge pattern gives rise, on the target surface, to a potential pattern which modifies the trajectories of the reading electron beams in the vicinity of the target.

II - 2 - 1 Coplanar control target

This is a fine periodic structure target consisting of alternate dielectric and conductive elements which can be shifted to different potentials. Two versions of such a target are shown in fig. 2a and 2b.

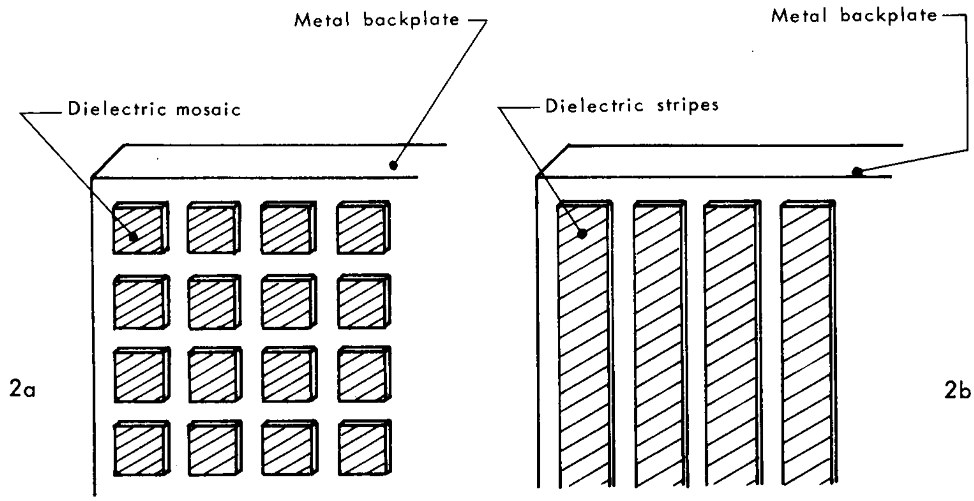

Fig 2 : Schematic views of coplanar control target

The target shown in fig. 2a consists of a mosaïc of dielectric deposited on a conductive material ; the target shown in fig. 2b consists of dielectric stripes deposited on a conductive material. In both cases the target may be considered as a planar structure since the dielectric thickness is negligible with respect to the surface dimensions of the elements. The simple symmetry of the structure shown in fig. 2b makes theoretical considerations easier and will be taken as an example for further discussion.

II - 2 - 2 Principle of coplanar control

The coplanar control utilizes the electrostatic interaction between neighbouring elements localized in the same plane in order to control the reading electrons incident on discrete elements of the target.

In the following discussion of the mechanism described here after, the reference potential (0) is that of the reading gun cathode and the target potential V_c is that of its conductive elements which are all at the same potential since they constitute a single metal backplate. This potential V_c can be controlled by an external voltage supply and will be shifted, in reading mode, to a low value, for example $V_c = +5$ V.

The surface potential of the dielectric being v and assuming as a first step that the dielectric areas of the target have not received any charge, the target potential is then uniform over the whole surface and $v = V_c$.

Due to the presence of a field mesh located in front of the planar target and close to it, a uniform decelerating field is established in the grid-target space when this grid is shifted to a high potential of about + 500 V. The equipotential lines in this space are shown in fig. 3 in the vicinity of the target.

The reading electrons, although arriving at reduced speed, have a sufficiently high energy to reach the target.

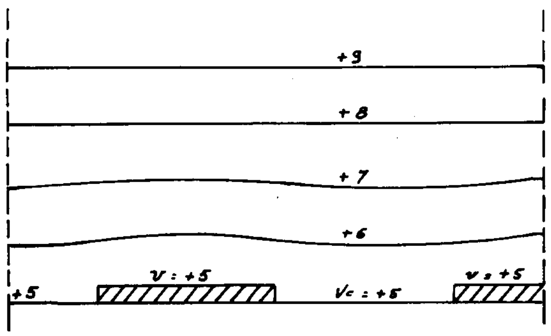

Fig 3 : Equipotentials in the vicinity of the target in the case of a non charged dielectric

Assuming, as a second step, that the dielectric areas of the target have been charged at a negative potential for example $v = -5$ V , equipotential lines obtained in the vicinity of the target are given in fig. 4.

This negative potential of the dielectric strongly disturbs the equipotential lines and as a result the electron trajectories are modified.

The electrons of the reading beam are repelled by this negative potential and no electrons land on the dielectric. A fraction of the electrons is reflected back to the field grid and the remainder will reach the conductive areas of the target.

Figure 5 shows the modifications of the electron trajectories due to the negative potential of the dielectric. These trajectories have been calculated by computer.

The equipotential lines (fig. 4) and the electron trajectories (fig. 5) show the phenomena in the vicitiny of the target for + 5 V on the target and - 5 V on the dielectric. For other values of the dielectric potential it is obvious that the fraction of reflected electrons will increase when the dielectric potential is more negative.

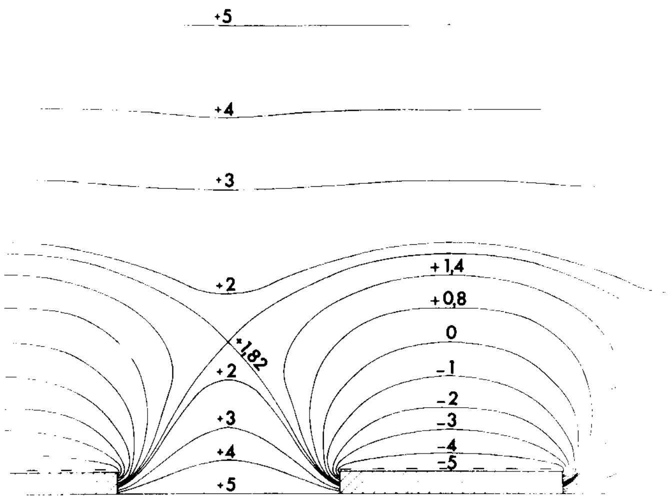

Fig 4 : Equipotentials in the vicinity of the target in the case of a charged dielectric (Vc = +5V ; v = -5V)

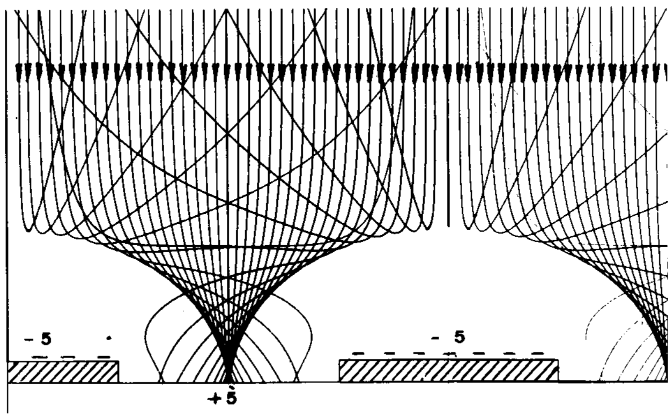

Fig 5 : Electron trajectories in the vicinity of the target in the case of fig 4

We can notice, on fig. 4, a saddle point in the potential distribution where the equipotential lines cross over.

For a dielectric potential v_{co} sufficiently negative (target cut-off potential), the potential of this saddle point can decrease to 0 V . In this case and for all dielectric potentials more negative, no electron will be able to reach any point of the target.

The influence of the dielectric potential on the number of electrons able to reach the target is illustrated by fig. 6 . The curves give the signal current (proportional to the number of electrons landing on the target) as a function of the dielectric potential v for different values of target potential V_C.

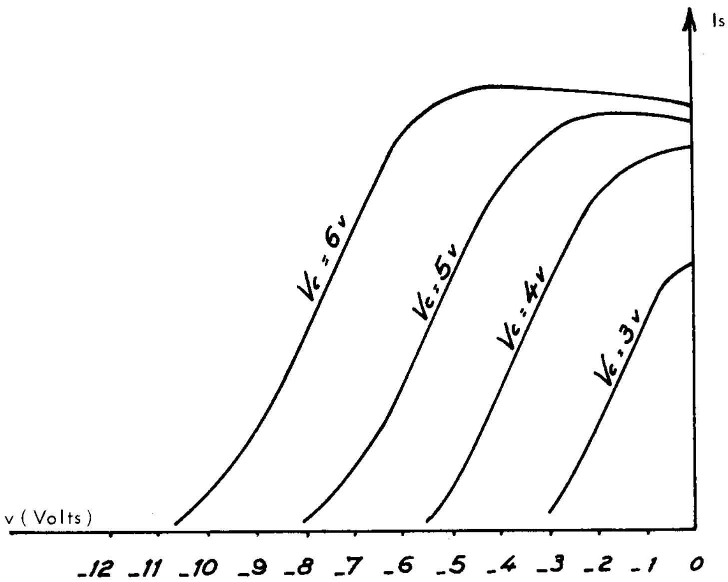

Fig 6 : Output signal amplitude versus Vc and v

II - 2 - 3 Reading characteristics by coplanar control

From the preceding considerations the results are that :

- the more or less negative potential established on the dielectric within a given zone of the target enables the control of the number of electrons landing on the conductive area of this zone.
- the control can be continuously varied from the cut-off to the maximum signal ; stored information can thus be released at different levels and half-tones be produced in the output.
- the dielectric which stores the information and also acts upon the reading beam as a control grid is at a negative potential and the electrons can never land on the dielectric : the stored information is not degraded by the reading beam (non destructive read-out).
- the reading electrons which are unable to land on the target are reflected towards the field grid ; a complementary signal can therefore be collected on this grid and it can be of interest to use this particularity for certain applications.

II - 3 - Negative or positive charge deposit on the dielectric - Erasing and writing (See figure 7).

The mechanism of non-destructive read-out assumes, as described hereabove, that the dielectric is at a negative potential with respect to the cathode which emits reading electrons. This potential can vary from target cut-off voltage v_{co} to 0 V depending on the information recorded on the point considered.

The negative pattern potential is established on the dielectric surface by the erasing and writing operations.

Only the operating principle is described in the following chapter, additional particular operating conditions will be given in the chapter concerning each type of tube.

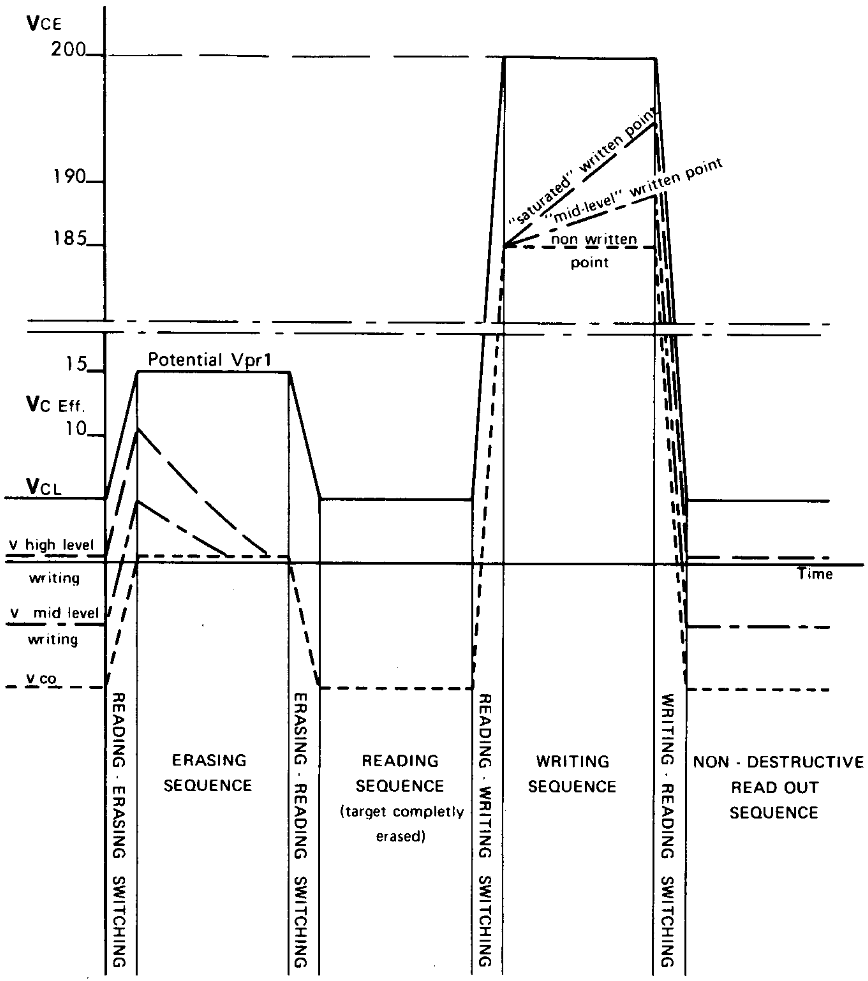

Fig 7 : Operating principle = erasing - writing - reading sequences

We shall design by :

V_{CL}	target potential in reading mode
V_{CEff}	target potential in erasing mode
V_{CE}	target potential in writing mode
v	dielectric surface potential in the considered element ΔS
v_{co}	target cut-off potential
c	target capacitance per unit area.

First of all, it is necessary to define the relation between dielectric potential v and target potential V_C.

An element of dielectric surface ΔS presents an elementary capacitance $c\Delta S$ with respect to the surroundings which is here the conductive area of the target.

Assuming this element ΔS to have a charge ΔQ , its potential v will be

$$v = V_C + \frac{\Delta Q}{c\,\Delta S}$$ with respect to the cathode emitting reading electrons.

It can be deduced from this relation that :

- the potential v of a dielectric element will directly depend upon the target potential V_C.
- it is possible to modify the dielectric potential in a positive or negative direction by depositing positive or negative charges ΔQ.

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These two phenomena are used in the mechanism of erasing and writing. Indeed the local variation of dielectric potential is always obtained by deposited charges, charges which are caused by electrons impinging on the dielectric. As we know (see chapter II-1) the impact of electrons can bring negative or positive charges depending on the potential of the dielectric with respect to the emissive cathode.

II - 3 - 1 - Erasing - Priming

This operation consists of shifting all points of the dielectric surface to the negative cut-off potential v_{co} whatever the former state may be. The dielectric is thus ready to receive new writing information.

For this end V_{CL} is switched to $V_{CEff} = V_{CL} - v_{co}$ and during this process, the dielectric potential is modified but the dielectric charges remain unchanged.

This potential which can be, before target potential switching, between 0 (saturated written point) and v_{co} (non written point), will take a value between $V_{CEff} - V_{CL}$ and $V_{CEff} - (V_{CL} - v_{co}) = 0$, with V_{CEff} and V_{CL} verifying the conditions $0 < V_{CEff} - V_{CL} < Vpr_1$ therefore, over the whole dielectric surface, the impinging electrons will bring the potential of different points down to the equilibrium potential 0 V.

If the target potential is then shifted from V_{CEff} to V_{CL}, the dielectric surface potential will become $0 - (V_{CEff} - V_{CL}) = v_{co}$.

It is then important to notice that by just the switching of the target potential from V_{CL} to V_{CEff} and again to V_{CL}, the potential of the dielectric surface has been made uniform and brought to v_{co} by the electron beam.

II - 3. 2. Writing

For this purpose, the dielectric potential is brought to a value between v_{co} and 0 assuming the dielectric potential to be $v = v_{co}$ which is obtained by erasing operation as described above.

Since the potential v must be brought to a higher value, it is necessary to deposit positive charges which is possible if v (during writing) is higher than Vpr_1. V_{CE} is shifted to a high positive value so that $v = V_{CE} - V_{CEff} > Vpr_1$.

When the element ΔS is bombarded by electrons, ΔQ is positive and its potential v will become :

$$V_{CE} - V_{CEff} + \frac{\Delta Q}{c\,\Delta S}$$

If the target potential is then shifted from V_{CE} to V_{CL}, the dielectric potential will be :

$$V_{CE} - V_{CEff} + \frac{\Delta Q}{c\,\Delta S} - (V_{CE} - V_{CL}) = v_{co} + \frac{\Delta Q}{c\Delta S}$$

The dielectric potential is thus brought (after writing) to a potential exceeding v_{co} by a quantity proportional to ΔQ.

Remarks :

1/ If ΔQ is sufficiently high v can become positive but this corresponds to an unstable state since the reading electrons will bring the potential v down to the equilibrium potential v = 0 ; on the other hand a coplanar effect, which is not discussed here, will limit ΔQ to a value slightly higher than $v_{co} \cdot c\,\Delta S$

2/ In the mechanism described above, switching of the target potential is utilized to bring the dielectric potential to the erasing condition ($v < Vpr_1$, deposition of negative charges) or the writing condition ($v > Vpr_1$, deposition of positive charges). But it is important to notice that, since primary electron energy is given by the potential difference between the dielectric and the emissive cathode those different operations can be obtained either by switching of cathode potential or without any switching by using several cathodes at different potentials.

3/ The target capacitance c is a fundamental characteristics since it binds the variations of the dielectric potential Δv to the amount of deposited charges ΔQ. This will have a direct influence on erasing speed, writing speed and remanence For a given charge ΔQ, the lower the target capacitance, the higher the corresponding Δv ; a low target capacitance will correspond to a high erasing speed, high writing speed and a low remanence.

II - 3. 3. - Case of a thin target able to accept charges from both sides = dual-gun target

Although the mechanism described above can be applied to this case, it is necessary to give some more information about the operating principle of a target used in dual-gun tubes.

A sample of this target is shown in fig. 8.

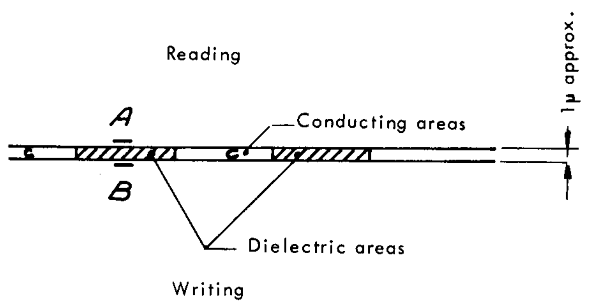


Fig 8 : Schematic view of thin target structure

It will be noticed that, on the reading side, the target presents the same conductor-dielectric periodical structure ; it will be sufficient to establish on this side of the dielectric a negative potential pattern ranging from v_{co} to 0 to obtain a coplanar control target.

The potential pattern is also obtained by depositing charges by either of the two guns.

In the case where charges are deposited by the reading beam, the operating principle is exactly the same as previously described.

In the case where charges are deposited by the writing gun, the mechanism is the following.

Let us consider a charge ΔQ deposited on the element B of surface ΔS . The potential of B varies then by a quantity $\Delta v_B = \frac{\Delta Q}{C_B}$, C_B being the capacitance of the element B with respect to the surroundings. Because of the geometrical dimensions of the target (very low thickness) the major part of Δv_B will be found in A . It is not our purpose to present here the calculation made for the quantitative evaluation of this phenomenon but as an approximation, we can estimate that the potential of the dielectric facing the writing gun is transferred on the reading side by capacitive division. This capacitive division between elements B, A and C is such that $C_{BA} \gg C_{AC}$ and practically $\Delta v_A \simeq \Delta v_B$

The structure of a target shown in figure 8 enables, provided the target is thin, to obtain a coplanar control target on which charges can be deposited on either side.

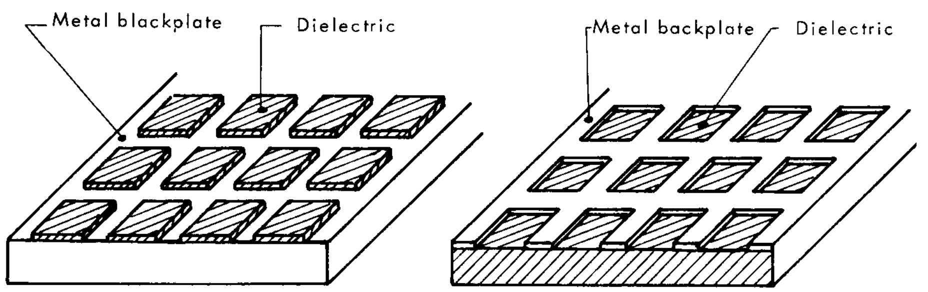
III - SINGLE GUN TME's

III - 1 General

The realization of single-ended TME's is based on the writing mode described in chapter II-3-2 (writing and reading performed on the same side of the target).

The target is made of a dielectric mosaïc deposited on a metallic plate (fig. 9 a). A single gun is sequentially used for erasing, writing and reading. The target capacitance per unit area (c) is determined only by the dielectric thickness and does not depend upon the mosaïc pitch and obviously upon the metal thickness.

A variant of the target (fig. 9 b) can consist of a metallic mesh deposited on a dielectric block. In this case the capacitance is determined by the pitch of the metallic wires and is practically independent of the dielectric thickness.



9a 9b

Fig 9 : Schematic view of single gun tube targets

The tubes described hereunder utilize essentially a target having the structure shown in fig. 9 a.

III - 2 TME 1238 and TME 1239

These single ended tubes are especially intended to store information provided as T. V. video signals or alphanumeric characters.

Their size is similar to that of a 1" Vidicon for TME 1238 and 1" 1/2 Vidicon for TME 1239 (see fig. 10). They employ electromagnetic focus and deflection and therefore can be used with standard Vidicon hardware.

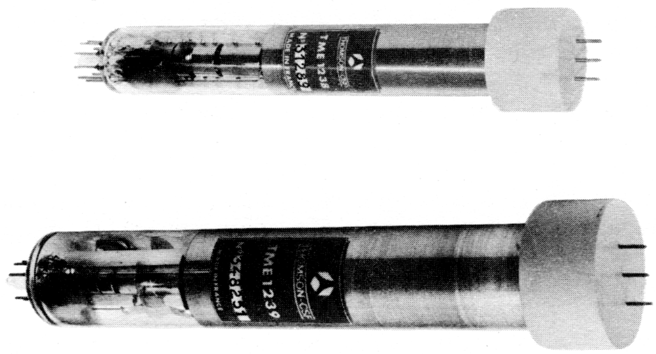


Fig 10 : TME 1238 and TME 1239

The pin configuration is also similar to a Vidicon. Furthermore the capacitance of the output signal electrode is such that it allows for the use of Vidicon type amplifiers. Thus, the associated electronics are quite similar to those used widely and inexpensively for Vidicons.

III - 2 - 1 Internal construction

Figure 11 shows the inside geometry of TME's . Essentially, they include an electron gun and a storage target.

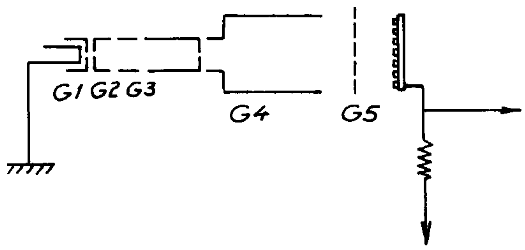


Fig 11 : Schematic view of single gun TME's

The electron gun consists of a cathode, a control grid G_1 , an accelerating electrode G_2 , a so-called erasing electrode G_3 (the operation of which is explained later), a focusing electrode G_4 and a field mesh G_5

This fine mesh (20 to 40 wires per mm) is located at close proximity to the storage target.

The target shown in fig. 9a is made of a heavily doped Silicon backplate on which silica is deposited. Square areas of insulating material have about 10 µm size equally spaced by 15 µm from each other. This target is made from a thin Silicon plate by using well-known integrated circuit technology.

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a - Silica deposited on the Silicon by a thermal oxidation process, has a uniform thickness of about 1 to 2 µm ;

b - Silica is covered by a photosensitive resin ;

c - Insolation is achieved by a photographic mask ;

d - The operations of skinning, silica etching and resin dissolving are achieved by using conventional processes.

This will give a silicon plate covered by squares of very compact, uniform and adhesive silica.

This structure offers significant advantages in terms of simplicity and ruggedness In addition the storage characteristics are unaffected by temperature variations.

III - 2 - 2 - Operating principle

During the different sequences (erasing - writing - reading) the cathode is constantly maintained at ground potential and δ ratio is modified by acting on the target potential.

The input signal, corresponding to the information to be stored, is applied to the control grid G_1.

The electron beam is magnetically focused and deflected then collimated so that the electron trajectories are perpendicular to the surface of the target. The metal backplate is used as the output signal electrode.

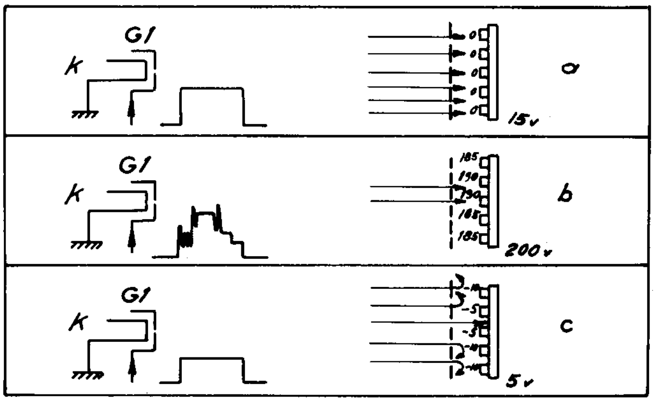

Fig 12 : Operating principle of single gun TME's

Figure 12 shows the potentials established on the metal and the dielectric during the three sequences of a complete cycle. It is important to remember that :

- in the erasing mode δ is lower than unity and the stabilized dielectric potential is OV i. e. the cathode potential ;

- in the writing mode δ is greater than unity and the potentials of dielectric zones bombarded by the electrons will increase by a few volts ;

- in reading mode, the scanning beam is modulated by the charge pattern stored on the target. Only electrons impinging on written points generate an output signal reproducing faithfully the stored information.

The signal output current develops a proportionate voltage through a load resistance, voltage which after amplification is applied to a standard display tube (T. V. monitor or other) where the stored image is displayed.

The retention time, as noted earlier, is theoretically infinite. In proctice, it is limited by two phenomena :

- progressive discharge of the dielectric target because of dielectric leakage current. Considering that the dielectric used is of high quality and its thickness is large in comparison to the low voltage applied to the target, this phenomenon usually has a negligible effect;

- creation of ions by the reading beam. Vacuum is not perfect inside the tube and the electrons of the reading beam ionize some molecules of residual gas. The positive ions created in the G_5 grid-target space are attracted by the negatively charged areas of the dielectric surface and progressively neutralize the stored charges.

The retention times given in the table below have a definite value limited by this secondary effect.

One of the key features of this tube is its capability of fast erasing of the stored image. Erasing time is a function, on one hand, of the capacitance of the storage dielectric and on the other hand of the intensitity of the erasing beam. Electrode G_3 permits increasing the erasing current in large proportion, when fast erasing is required.

In the reading mode, electrode G_3 is at the potential of the accelerating electrode G_2 and has no effect on the beam ; the diaphragm is therefore fully efficient and only a low current fine spot size beam emerges from the electron gun.

For fast erasing, the G_3 electrode potential is modified in such a way that all the current is focused on the diaphragm. The, latter is therefore not effective anymore and the beam current emerging from the gun is increased by a factor ranging from 10 to 30, thereby achieving the fast erase characteristic.

Remarks

- Destructive read-out

In many applications, it is necessary to gradually erase the "old" information so that it does not interfere with the "new". This function can be easily achieved with a TME by performing partial erasure during the non-reading periods (for instance during line retrace in the case of T.V. scan). Figure 13 shows that progressiveness of erasing can be varied in large proportions by adjusting the erasing current.

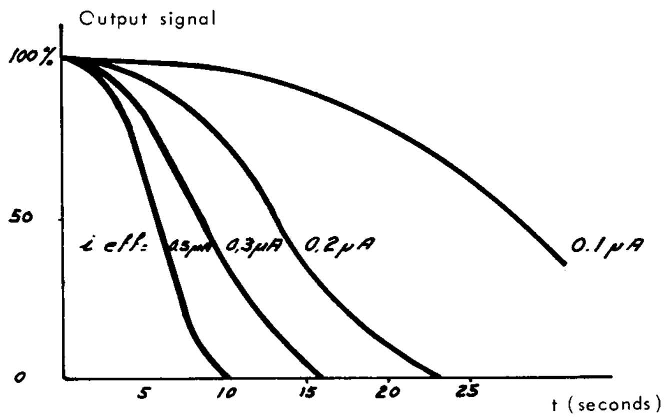

Fig 13 : Progressive erasure of stored signal

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- Permanent memory.

A mask reproducing a certain pattern can be used during the manufacturing of the target, so this pattern becomes permanently "printed" on it. For example, the terrain surrounding an airport can be printed on a TME target and the corresponding image can be superimposed on the radar image. The permanent memory can also be a map, reference points, characters and the like.

III - 2. 3. - Performance

Performance of TME 1238 and TME 1239 are as follows :

	TME 1238	TME 1239
Writing speed		
- For overall target area in standard T.V. scan	33 to 40 ms (1 T.V. frame)	33 to 40 ms (1 T.V. frame)
- for one target diameter	50 µs	50 µs
Storage time		
- with reading beam turned-off	a month	a month
Output signal current		
- for performance as follows	0.2 µA	0.2 µA
Output capacitance (target)	5 pF	10 pF
Resolution		
- measured by orthogonal read-write at 50 % modulation	800 T.V. lines per diameter	1200 T.V. lines per diameter
Gray scale		
- Number of half-tone levels	10	10
Retention time with constant reading in standard T.V. scan		
- for a gray scale image	min. 5 mn	min. 10 mn
- for a black and white image	min. 10 mn	min. 15 mn
Erasing time		
- fast erasing, by switching of the erasing electrode, down to noise level	33 to 40 ms (1 T.V. frame)	33 to 40 ms (1 T.V. frame)
- normal erasing, with no switching of the erasing electrode, down to 10 % of the initial signal level	120 ms	250 ms

The values mentioned in the above table call for the following comments :

- Writing speed

It refers to the writing of a signal up to the saturation level. Significantly higher speeds can be achieved at a lower writing level. It is then possible to increase this level especially when only two tones are desired (black and white).

- Retention time

The degradation of stored information occurs only when reading, it is possible, without reading (beam cut-off) to store it for a month.

- Output signal current

The 200 nA current is capable of achieving an equivalent signal/noise ratio of 200 with a 3 nA RMS noise - 7 MHz bandwidth amplifier. Higher values of output current are possible with a slight degradation of both the resolution and the retention time, whereas lower values of output current will have the opposite effect. Extreme values are typically 20 nA and 1 μA.

- Resolution

It corresponds to a 50 % modulation of the output signal at the center of the target. Fig. 14 shows the modulation transfer function at the center of target.

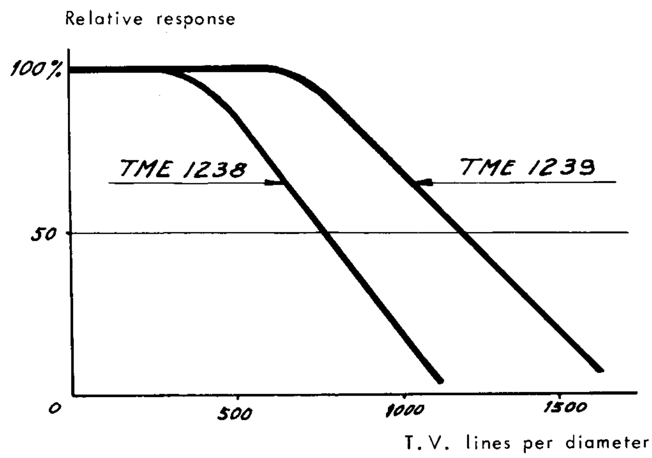

Fig 14 : Modulation transfer function of TME 1238 and TME 1239

- Gray scales

Figure 15 permits a more precise evaluation of the gray scale reproduction. It shows the overall read-write response of the tube.

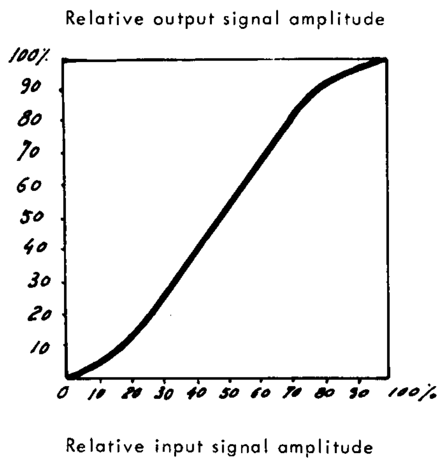

Fig 15 : Signal - Signal transfer function

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- Reading time (with continuous reading)

Figure 16 shows the output signal characteristics of the TME 1238 and TME 1239 as a function of time during a standard T. V. read-out mode for saturation-written and non-written areas. The rise of the "black" current corresponding to non-written areas is caused by positive ions discharging the surface of the target.

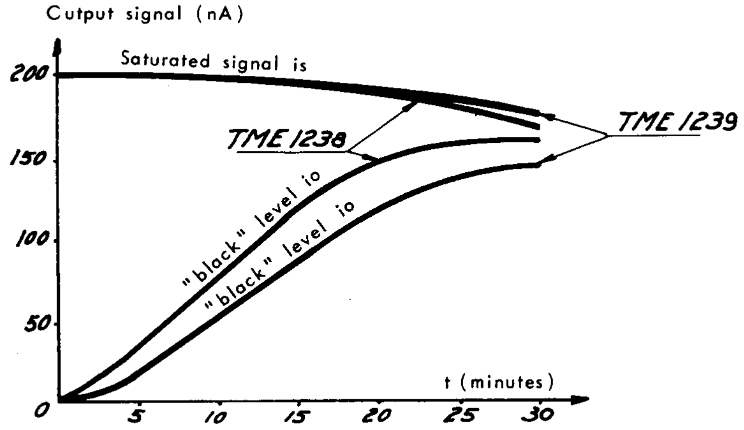

Fig 16 : Variation of signal versus time, remanence

- Uniformity

Figure 17a shows a picture stored in a TME and displayed on a T. V. monitor
It gives a qualitative idea of background and signal uniformity as well as of the reproduction of gray shades which is quite similar to a camera tube. It must be noted that it is possible to read only one part of the stored image (Zoom effect) as shown in figure 17b.

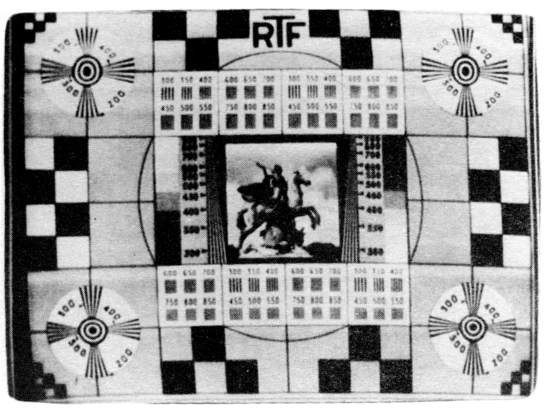

Fig 17a : Recorded image on the TME 1239

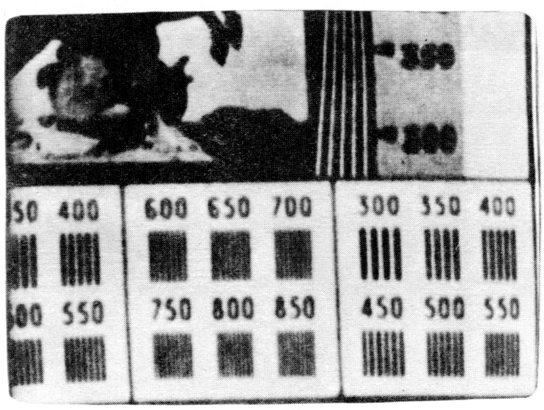

Fig 17b : "Zoom" effect : portion of the image shown in fig 17a

Figure 18 shows a two level picture application where a TME is used to store and display alphanumerics.

Figure 19 demonstrates the possibility of local and precise erasing offered by the TME's (line marked by an arrow on fig. 18 is erased on fig. 19).

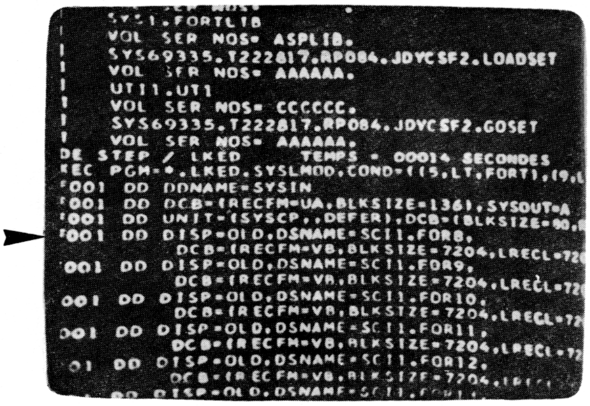

Fig 18 : Character recording

Fig 19 : Selective erasure of some characters

- Integration

Figure 20 shows the amplitude of the output signal versus the number of writing scans at low level. A point of interest is the excellent linearity of the useful part of the curve.

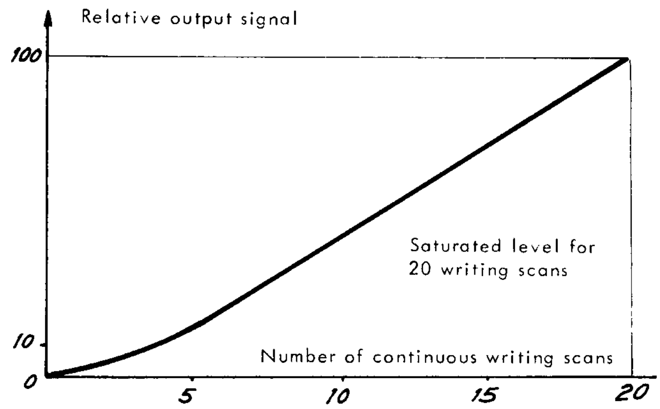

Fig 20 : Integration characteristic

III - 3 - Other single-gun TME's

Several tubes based on the same principle as the TME 1238 and TME 1239 have been or are being developed. Scientists are working actively to develop especially : an electrostatic focus and deflection tube, a high writing speed tube and a high resolution tube.

III. 3. 1 - Fully electrostatic TME 1348

This tube has a size similar to the TME 1239 but utilizes electrostatic focus and deflection. The main advantages of this system are the following :

- Reduction of equipment weight by the elimination of coils.
- Reduction of focusing and scanning power resulting in further reduction of equipment weight.
- More precision in positioning a "read point" from a stored image (more precise addressing).
- Better image raster.

On the other hand, those advantages result in decreased resolution (600 T. V. lines at 50 % modulation) which is only the half of the resolution obtained with a corresponding electromagnetic TME.

III. 3. 2 - TME with better resolution

The resolution of a TME depends upon :

- the spot size
- the fineness of target mosaïc
- the overall surface of the target.

It is possible, by optimizing these 3 parameters, to improve the resolution which is now 1200 T. V. lines for the TME 1239. Work is now underway which will increase the useful area of the target and improve the fineness of the mosaïc ; the problem is the fact that it is difficult to maintain a fine spot size over a greater target area. The use of Silicon plates of 60 mm diameter allows for a resolution of 2000 to 2500 T. V. lines at 50 % modulation.

III. 3. 3 - TME with high writing speed

The target capacitance c (see chapter II. 3) of the TME 1238 and TME 1239 allows for the writing and erasing of the target in 40 ms and a retention time in the order of 10 mn with continuous read-out. These tubes are specially intended to store T. V. images.

It is however possible, by modifying the capacitance c of the target, to increase the writing and erasing speed if a less long retention time is required.

Tubes of this type, offering lower target capacitance are now being developed. The reduction of c capacitance by increasing the dielectric thickness will however involve a less fine structure of the mosaïc thereby altering the resolution. The writing speed can also be increased by increasing the beam current which also will involve a decrease of resolution, since the spot diameter will increase in accordance with the beam current.

Although the development of these tubes is not over, it seems that it offers considerable promise for obtaining a writing speed of 1 µs per target diameter with a resolution of 600 T. V. lines per diameter (this speed is 50 µs for TME 1238 and TME 1239).

IV - TME's WITH THIN TARGET

IV - 1 General

The properties of a thin target described in chapter II. 3. 3 are used for the realization of TME's ; specially for dual-gun tubes which permit simultaneous writing and reading. We will specially describe hereafter the TME 1496 the development of which is now completed.

IV. 2 - TME 1496

IV. 2. 1 - Construction

The TME 1496 shown in figure 21 is a double-ended tube of small size, operating at low voltage mode and requiring associated electronics relatively simple and inexpensive.

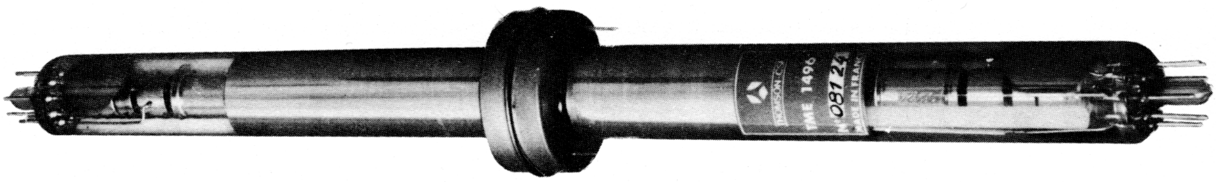

Fig 21 : Double gun TME 1496

It includes two electromagnetic focus and deflection guns and can use standard 1" Vidicon hardware.

Schematic view of its structure is shown in figure 22. It includes on both sides of the thin target, 2 field meshes and two guns quite similar to that of TME 1238 described in chapter III. 2. 1.

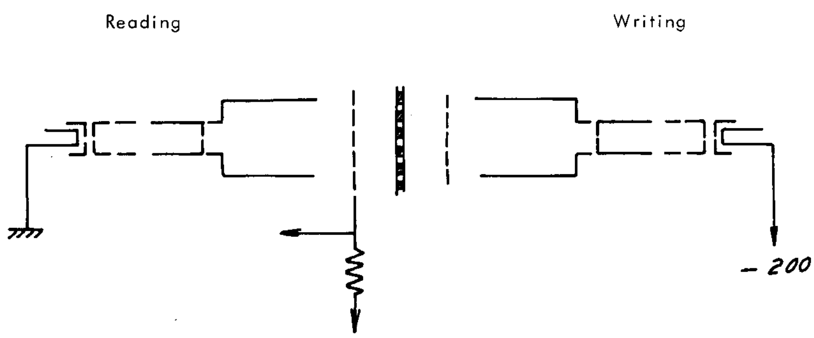

Fig 22 : Schematic view of the TME 1496

IV. 2. 2 - Operating principle

Operating principles of this tube are illustrated in figure 23.

- Writing (fig. 23 a)

We assume that, after an earlier erasing, the dielectric surface facing the reading side is at -10 V and the writing electron beam scans the target with an intensity modulated by the signal applied to the wehnelt.

Considering that the potential difference between the target and the writing cathode is high enough (about 200 V) to have a coefficient $\delta > 1$, positive charges are deposited which increase the potential of the written point by +5 V on the writing side.

By capacitive coupling the potential of the corresponding point on the reading side will increase by a value of about 5 V and thereby its potential is shifted from -10 V to -5 V.

- Reading (fig. 23 b)

The reading is performed by scanning the target by an unmodulated beam as described in chapter III. 2. 2. for single ended tubes.

- Erasing

This can be done by using either the writing beam (fig. 23 c) or the reading beam (fig. 23 d).

In the first case, the target is at -185 V ; the writing electrons landing on the dielectric (writing side) with an energy of 15 eV and giving rise to a secondary emission ratio $\delta < 1$, the dielectric is then brought, after bombardment, to an equilibrium potential of -200 V that is -15 V with respect to the target metal backplate.

In the second case, the erasing is achieved by a mechanism identical to the single-gun TME's.

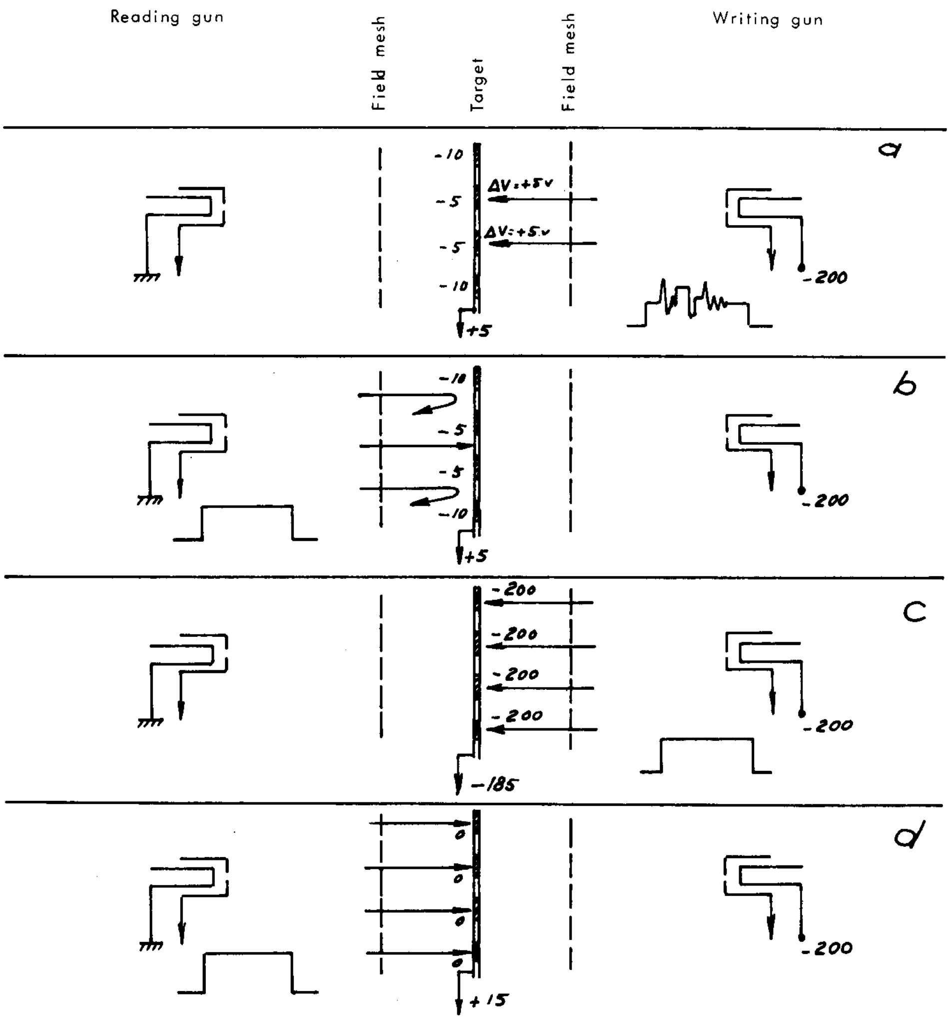

Fig 23 : Operating principle of the TME 1496

Only the major operations are described here since this tube exhibits many variations of operation which can respond to any desired application.

For example, only the writing mode achieved by the writing gun has been described. It is obvious that this operation may be achieved by the reading gun by switching, for example, of the target voltage. It is also possible to conceive, for a radar application, a gradual variable erasing by the writing gun and automatic switching in writing mode just as the echoes begin to appear.

Furthermore, it must be noted that there will be no crosstalk thanks to the effective isolation between the reading and writing sections. For this purpose, the signal is not collected on the target but on the field mesh located at the reading side, as shown in chapter II. 2. 3.

VI. 2. 3 - Performance

Performance of TME 1496 are as follows :

- Writing speed : for the overall target area	33 to 40 ms (1 T. V. frame)
- Storage time with reading beam turned-off	a month
- Output signal current	0. 2 μA
- Output capacitance (target or field mesh)	approx. 10 pF
- Resolution measured by orthogonal read-write at 50 % modulation	800 T. V. lines/diameter
- Retention time with continuous read-out	5 to 10 mn
- Erasing time for the overall target with erasing by either gun	33 to 40 ms (1 T. V. frame)

The examination of the above mentioned performance characteristics demonstrates that the results obtained from the dual-ended TME 1496 are very similar to those mentioned in chapter III. 2. 3. concerning the TME 1238.

Figure 24 shows an image stored by a TME 1496 ; the black zones have been selectively erased in the right upper corner by the reading gun and in the left lower corner by the writing gun.

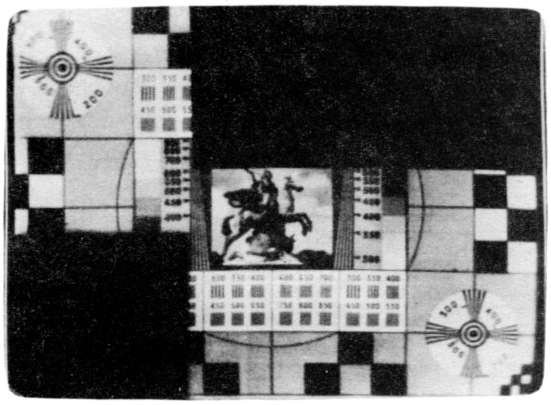

Fig 24 : Image recorded on the TME 1496 and selectively erased by both guns

IV. 3 - Other TME's with thin target

Although the studies of these tubes are not yet completed, it is of interest to note the development of two tubes of this type.

First, a tube having a structure similar to the TME 1496 but exhibiting higher resolution. We are working especially to increase the useful target diameter in order to reach a resolution ranging from 1000 to 1500 T. V. lines per diameter.

The second developmental tube has a structure and a utilization slightly different, since the input is a luminous signal. In this tube the writing gun is replaced by a photocathode associated to an image transfer. Such a tube can permit the integration and the storage of low light level images by using the integration properties of the TME targets.

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